CLAIMS

1. A method for yielding transient solutions for the film-blowing process by using a film-blowing process model characterized that the following governing equations in consideration of the viscoelasticity and cooling characteristics of the film are first solved; and then, through coordinate transformation, the free-end-point problem is changed into a fixed-end-point problem; and finally, by introducing Newton's method and OCFE (Orthogonal Collocation on Finite Elements), the transient solution for the film blowing process is obtained:

Equations:

$$\frac{\partial}{\partial t}\left(rw\sqrt{1+\left(\frac{\partial r}{\partial z}\right)^2}\right)+\frac{\partial}{\partial z}(rwv)=0 \qquad \ldots(1)$$

Here,

$$t=\frac{\bar{t}\,\bar{v}_0}{r_0},\ z=\frac{\bar{z}}{r_0},\ r=\frac{\bar{r}}{r_0},\ v=\frac{\bar{v}}{v_0},\ w=\frac{\bar{w}}{w_0}$$

Axial direction:

$$\frac{2rw[(\tau_{11}-\tau_{22})]+2r\sigma_{surf}}{\sqrt{1+(\partial r/\partial z)^2}}+B(r_P^2-r^2)-2C_{gr}\int_0^{z_L} rw\sqrt{1+(\partial r/\partial z)^2}\,dz-2\int_0^{z_L} rT_{drag}dz=T_z \qquad \ldots(2)$$

Here,

$$\overline{T_z}=\frac{T_z}{2\pi\eta_0 w_0 v_0},\quad \overline{B}=\frac{\overline{r_0^2}\Delta P}{2\eta_0 w_0 v_0},\quad \Delta P=\frac{A}{\int_0^{z_L}\pi \overline{r}^2 d\overline{z}}-P_a,\quad \overline{\tau_{ij}}=\frac{\tau_{ij}\tau_0}{2\eta_0 v_0}$$

$$C_{gr}=\frac{\rho g \overline{r_0^2}}{2\eta_0 v_0},\quad \overline{T_{drag}}=\frac{T_{drag}\overline{r_0^2}}{2\eta_0 v_0 w_0},\quad \overline{\sigma_{surf}}=\frac{\sigma_{surf}\tau_0}{2\eta_0 v_0 w_0}$$

Circumferential direction:

$$B=\left(\frac{\left[-w(\tau_{11}-\tau_{22})+2\sigma_{surf}\right](\partial^2 r/\partial z^2)}{\left[1+(\partial r/\partial z)^2\right]^{3/2}}+\frac{w(\tau_{33}-\tau_{22})+2\sigma_{surf}}{r\sqrt{1+(\partial r/\partial z)^2}}-C_{gr}\frac{\partial r/\partial z}{\sqrt{1+(\partial r/\partial z)^2}}\right)$$

...(3)

Constitutive Equation:

$$K\tau+De\left[\frac{\partial \tau}{\partial t}+v\cdot\nabla\tau-L\cdot\tau-\tau\cdot L^T\right]=2\frac{De}{De_0}D$$

...(4)

Here,

$$K=\exp[\epsilon De\,\mathrm{tr}\,\tau],\quad L=\nabla v-\xi D,\quad 2D=(\nabla v+\nabla v^T),\quad De_0=\frac{\lambda \overline{v_0}}{\overline{\tau_0}},$$

$$De=De_0\exp\left[k\left(\frac{1}{\theta}-1\right)\right]$$

Energy equation:

$$\frac{\partial\theta}{\partial t}+\frac{1}{\sqrt{1+(\partial r/\partial z)^2}}\frac{\partial\theta}{\partial z}+\frac{U}{w}(\theta-\theta_c)+\frac{E}{w}(\theta^4-\theta_\infty^4)=0$$

...(5)

Here,

$$\theta = \frac{\bar{\theta}}{\theta_0},\ \theta_c = \frac{\overline{\theta_c}}{\theta_0},\ \theta_\infty = \frac{\overline{\theta_\infty}}{\theta_0},\ U = \frac{\overline{U}\overline{r_0}}{\rho C_p \overline{w_0}\overline{v_0}},\ \overline{U} = \alpha\left(\frac{k_{air}}{\overline{z}}\right)\left(\frac{\rho_{air}\overline{v_c}\overline{z}}{\eta_{air}}\right)^{\beta},\ E = \frac{\epsilon_m \sigma_{SB}\overline{\theta_0^4}\overline{r_0}}{\rho C_p \overline{w_0}\overline{v_0}\theta_0}$$

Boundary conditions:

$$v = w = r = \theta = 1,\ \tau = \tau_0 \qquad \text{at } z=0 \qquad \ldots(6a)$$

$$\frac{\partial r}{\partial t} + \frac{\partial r}{\partial z}\frac{v}{\sqrt{1+(\partial r/\partial z)^2}} = 0,\ \frac{v}{\sqrt{1+(\partial r/\partial z)^2}} = D_R,\ \theta = \theta_F \qquad \text{at } z=z_F \qquad \ldots(6b)$$

wherein, r denotes the dimensionless bubble radius, w the dimensionless film thickness, v the dimensionless fluid velocity, t the dimensionless time, z the dimensionless distance coordinate, ΔP the air pressure difference between inside and outside the bubble, B the dimensionless pressure drop, A the air amount inside the bubble, P_a the atmospheric pressure, T_z the dimensionless axial tension, C_{gr} the gravity coefficient, T_{drag} the aerodynamic drag, σ_{surf} the surface tension, θ the dimensionless film temperature, τ the dimensionless stress tensor, D the dimensionless train rate tensor, ε and ξ the PTT model parameters, De the Deborah number, θ_0 the zero-shear viscosity, K the dimensionless activation energy, U the dimensionless heat transfer coefficient, E the

dimensionless radiation coefficient, k_{air} the thermal conductivity of cooling air, ρ_{air} the density of cooling air, η_{air} the viscosity of cooling air, v_c dimensionless cooling air velocity , α and β parameters of heat transfer coefficient relation, θ_c the dimensionless cooling-air temperature, θ_∞ the dimensionless ambient temperature, ε_m the emissivity, σ_{SB} the Stefan-Boltzmamn constant, ρ the density, C_p the heat capacity, D_R the drawdown ratio;

the assumption was made that no deformation occurred in the film past the freezeline at the boundary conditions; overbars denote the dimensional variables; subscripts 0, F and L denote the die exit, the freezeline conditions and the nip roll conditions, respectively; and subscripts 1, 2 and 3 denote the flow direction, normal direction, and circumferential direction, respectively.

2. The method for yielding transient solutions for the film-blowing process by using a film-blowing process model according to claim 1, wherein the non-isothermal process model is a numerical scheme for yielding transient solutions for the film-blowing process, which has three multiplicities.

3. In a nonlinear stabilization analysis method of a process, the improvement comprising that it is an analysis method that utilizes the temporal pictures obtained from the numerical scheme in Claim 1.

4. A method for the optimization of the process which is obtained by use of a sensitivity analysis of the relative effects affecting the stability of each process variable through a transient solution, which was calculated and yielded in the course of deduction of the transient solutions for the film-blowing process in Claim 1.

5. An apparatus necessary for the optimization and stabilization of the process, which utilizes the numerical scheme stated in Claim 1.